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6. AUTHOR(S)
Prof. James Lukens

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

State University of New York at Stony Brook
Dept. of Physics & Astronomy
Stony Brook, NY 11794-3800

8. PERFORMING ORGANIZATION REPORT NUMBER

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13. ABSTRACT *(Maximum 200 Words)*

Equipment has been acquired for an Electron Beam Lithography (EBL) system. This system is based on a Leo 1550 SEM with a Raith beam blanker and Raith Elphy Quantum software. The system has been used for the fabrication of SET devices with 30nm dimensions as well as multi-layer superconductor circuits based on the niobium trilayer process.

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Final Technical Report

Acquisition of a scanning electron microscope for electron beam lithography.

Funding from this grant has been used to acquire a new electron beam lithography (EBL) system based on a Leo 1550 SEM and Raith Elphy Quantum pattern generator software. This system has been installed and used for EBL. It substantially improves our ability to fabricate and inspect devices required for our research programs, as discussed below.

Equipment purchased.

Leo 1550 SEM with the following accessories:

- Raith electrostatic beam blanker, 1550-EBBUSPC
- Raith pattern generation hardware and software, Elphy Quantum
- Coolwell chiller, 960610
- Specimen current meter, 1550-SCM
- Stage control software, 1550-allstage
- Dual mag control, 1550_dualmag
- Backscatter electron detector, 1550_4QBSE
- HP deskjet printer, 1600M, for image printout
- HP Workstation for device design

Our previous EBL system was based on an AMRAY SEM and had EBL hardware and software of our own design. The key improvements provided by our new system are as follows:

- Faster writing speed: The Leo-Raith system has a minimum dwell time per point of 3μs. This is particularly important since it permits us to use much high sensitivity negative E-beam resists, e.g. Shipply UVN30. This in turn greatly increases our process flexibility.
- Automatic registration: Our processing is done on 2" wafers. It is, of course, impossible to write an entire wafer using a SEM-based EBL system. In general, we pattern the coarser, large scale, features using DUV photolithography in PMMA. After development, the wafer (with the same resist layer) is placed in the EBL system where the high-resolution parts of the pattern are written in a series of 500 μm fields. Since registration of the EBL and photolithographic patterns are required for each field, auto registration is essential for more complex circuits that require perhaps several hundred such registrations per wafer.
- Improved documentation: Since the EBL software and hardware for our new system are commercial, they have much more complete documentation than our homemade system. This makes the system much more easily accessible to others for a wider range of projects. Further, the EBL software is Windows based whereas our homemade system was written in HP basic which runs on an HP workstation and is rapidly becoming obsolete.
- Beam characteristics: The Leo SEM has a heated field emission source. This provides a much brighter and more stable beam compared to the LaB_6 source on our old system.

The one aspect in which the Leo-Raith system is inferior to our previous system is its lack of a laser interferometer to monitor the stage position to the 0.1 μm accuracy required for pattern stitching between EBL fields. Laser monitored stages are available for the Leo system, but exceeded our budget. We hope to add this option at a later date.

Status

The system was delivered in November 1998 with a beta version of the Elphy Quantum software. Since that time we have worked with Raith on the upgrade of the software package and solved several problems with the Leo SEM. The system has not yet been formally accepted due to excessive stage vibration which limited the viewing resolution to somewhat less than the 1 nm specs (but still much better than our AMRAY). This does not effect the EBL capability of the system, which is now our main EBL tool. Leo has recognized this problem and has agreed to provide an improved stage, which we expect to receive in a month or two. Two examples of the work we are now doing with the Leo system are shown in Figs. 1 and 2. Figure 1 shows a SET junction in an Al film, which was fabricated as part of our AFOSR funded project on Single electronics. Figure 2 shows a micrograph of some patterns written in negative resist, which were referred to above.

In addition to our AFOSR funded projects on Single Electronics, this new EBL system is also used for several other projects involving device fabrication:

- ONR supported work (in conjunction with HYPRES) to develop and demonstrate ultra-high speed RSFQ circuits
- A NRAO supported project to develop and fabricate SIS mixers for the MMA telescope, which is being constructed in Chile with NSF support.
- A NSA supported project to investigate SQUIDs as qubits for use in quantum computers.

Figures

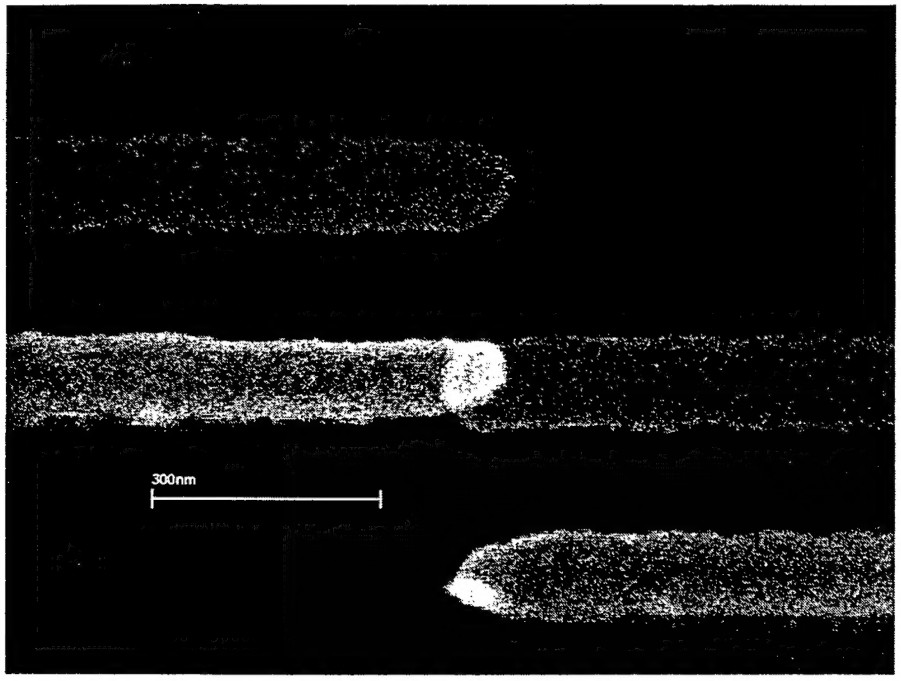

Figure 1. Micrograph of SET junction formed with Al electrodes. The pattern for the self-aligned mask was written using the Leo-Raith EBL system

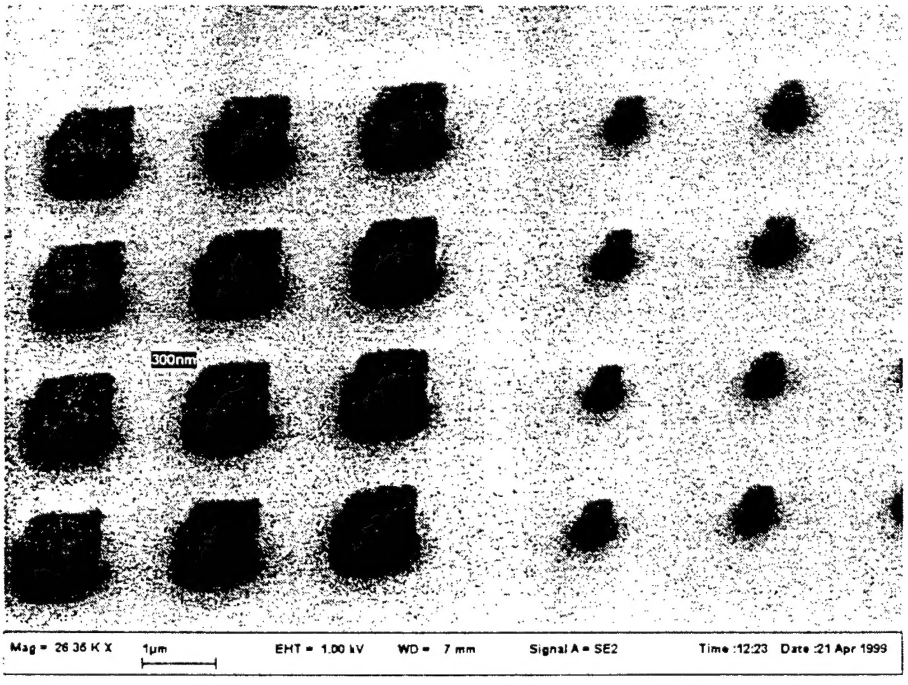

Figure 2. Micrograph of patterns written in Shipply UVN30 negative EBL resist using the Leo-Raith EBL system.